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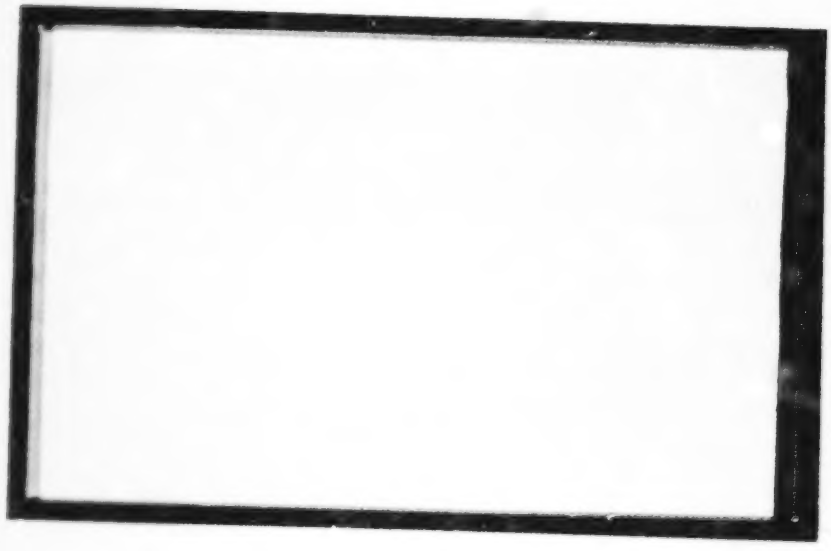

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# ACCIDENTS AND THEIR CAUSES: A NEW APPROACH

by

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The first point I would like to discuss concerns the nature of accidents themselves. The term 'accident' we seem to use in two senses: in the first to identify a particular class of phenomena by means of their characteristic effects. In most countries road accidents are required by law to be officially reported only if they cause injury, although in some countries those that cause a certain amount of 'damage only' must also be reported.

An important consequence of the use of such injury/damage criteria is that any event that results in the specified effects will tend to be called an 'accident', no matter what its form and causes may have been. This is true of cases of suicide and homicide (Macdonald, 1964) as well as - from our own experience in England - of injuries that happen in the course of passenger use of public transport (e.g. being thrown over), and even deaths to pedestrians as a result of ill-health (e.g. following sudden cardiac arrest). In other words the specific causes may be quite unrelated to conventional use of the transport system, but if the results include injury/damage the event will tend to be called an accident. Tabulated accident data may be misleading, for this reason, since the uniformity of the effects tends to mask and obscure the actual variance in their antecedent causes.

However, it is the other meaning of the notion of an accident-that in which the accident also means 'chance' - that has been the more damaging to Road Safety research and accident prevention. Effectively, since 'chance' signifies an event that lacks a cause, this meaning of the notion of an accident has tended to inhibit the investigation of accident causes, as stable and recurrent processes of road user movement and interaction. To illustrate how research has recently begun to make such investigations, I shall characterize the major research 'paradigms' that have been devel-

oped over the years, after examining the role of 'chance' and 'cause' in science and accidental events.

In the history of science the concepts of cause and chance have usually been taken to be independent and opposed: the one excludes the other. Their separation can in fact be traced back to the origins of science in the 15th and 16th centuries, when the classical experimental method began to be developed. As is well known, the procedure that arose to permit the isolation and investigation of scientific law, involved the reproduction of phenomena under controlled conditions. Such conditions were intended to control for the influences of chance effects. Later in its development, having thus controlled chance through the experimental method in the laboratory, science found it necessary to use the theory of probability, in order to achieve the same end theoretically, with greater precision. Later still, from about 1857, when the concept of a statistical distribution was first used in Physics (Maxwell), probability concepts came more and more into use in natural science and came to exclude the more traditional and detailed type of causal analysis, until in the present century quantum mechanics was founded explicitly on probability considerations without reference to any causal assumptions.

What is important about this historical sequence is the confirmation it provides of the objectivity and unity of 'chance' and 'cause'. The fact that science had eventually to incorporate probability and allow for 'chance' in its investigations shows clearly that the separation of 'chance' and 'cause' is only relative. Even the most careful experimental design and analytic 'treatment' cannot completely exclude the possible effects of chance. Outside the laboratory, in the natural world, where uncontrolled accidents are more likely to happen, the two more clearly occur together. All causal events have their 'chance' characteristics, and all chance phenomena have their causes.

Some examples should help to make this unfamiliar unity more clear. The theory of probability emerged in response to certain questions in gambling, especially dicing. The dice are constructed so as make it impossible for the gambler to predict the result of the next throw. This is a matter of chance. The gambler knows only what causal law and the rules of the game dictate, namely that when he throws the dice they will roll on the playing surface, and come to rest with one face of each die showing upwards. It is a matter of chance how many times they roll and whether they come to rest with their corners pointing towards the gambler or at an angle to him. One could go on naming the chance aspects of this kind of 'contingent' event, each of them being nonetheless the effects of familiar causal laws and conditions.

In driving, the fact that we turn a corner at a speed of, say, 2 kilometres per hour, at an average distance from the kerb of 1.00 rather than 1.01 metres, may be seen as a matter of chance in relation to the causal purpose of our actions, namely to complete the cornering manoeuvre. But as 'chance' characteristics of that manoeuvre, the precise speed and path of the vehicle still have their causes, however, much they may vary with such factors as the drivers' care, the curvature of the road, the traffic density, etc... But suppose an accident happens when the car collides with a pedestrian at the corner. It may be viewed as a matter of chance that the pedestrian was, let us say six feet tall, male and was wearing a hat. If these factors remained merely incidental to the accident this would not necessarily mean that they had no cause. Rather one would recognize their causal independance and look to the individual's genetic endowment, his dress preference, etc..., for an explanation. But if the pedestrian's sex, height and appearance meant that he was both more visible to the car driver and more able to move out of the path of the approaching car, then those same 'chance' characteristics could have determined whether

or not the accident took place or the degree of injury sustained by the pedestrian. From this example, it is clear that the factors that operate as effective causes, and those that remain as mere 'chance', depend on the circumstances of the given case.

The examples of a pedestrian's height, sex and appearance may be thought of as quite untypical as accident causes, but this is unlikely to be true of the previous illustrations of the cornering vehicle's speed and manoeuvring path. Such dimensions are central to road user control, and it may be seen as quite common that differences of 0.5 k.p.h. in speed, or one centimetre in separation distance can be the difference between an accident and a 'near miss'. Thus driver behaviour and road user control more generally, can be seen as the principal factor that ensures that such incidental variation remains a matter of chance rather than developing into an accident cause.

## THE INVESTIGATION OF ACCIDENT CAUSES

The earliest studies of accidents were purely statistical in approach and were concerned with industrial rather than road accidents. Investigators such as Greenwood and Newbold examined the distribution of reported injuries and damage. (The following short survey draws mainly upon Shaw and Sichel, (1971)). The conclusions reached associated accidents with particular occupations, groups of individuals, specific types and places of work, etc... Causation, at this time and using such methods, could only be inferred from the data. Viteles (1932) had objected to the convention he saw of focussing on factors that were related to 'accident susceptibility' through the study of groups of individuals, and had opposed to it (in the interests of accident prevention) an examination made from a personal and psychological point of view. By 1939, when Farmer and Chambers used psychomotor and psychological tests to help articulate the personal element in accident causes and substantiate their use of the con-

cept of accident proneness, the practise of identifying causes as individual factors in the driver's psychology was well established.

Thus, even by this date the paradigm of research was such as to statistically associate the causes of an individual's accidents with the individual's personal characteristics, defined in psychological and biographical terms. The actual antecedent causal relations involved - how particular factors produced accidents - were implied but could not be demonstrated. Through the succeeding years, from the war on up to the mid-'60's, this remained the predominant research orientation. The notion of 'accident proneness' went through changes, however. For example, a reorientation away from the individual psychological characteristic considered in isolation from the practice of driving, was introduced by Tillman and Hobbes, working in Canada, in 1949. Following their correlation of accident records with social indices of parental divorce, criminality and delinquency, exploration began to be made of a constellation of social maladjustment that included a high accident record as one factor. Still however, causality was implicit to the association between the individual's social and psychological nature and his accident record. Insofar as the usual method in these studies was correlational in nature, the individual's accident experience was being made synonymous with his other characteristics. Accidents were being treated as simple manifestations of the road user's individual nature. Moreover causality was being confused with the notion of responsibility, as defined by the courts. There was a risk that the function of the courts to apportion blame and responsibility would be preempted and analysis denied.

Mostly the research studies made were carried out by psychologists, who simply applied the tests and methods developed by psychology to road safety and to drivers. Little recognition was made of the actual driving task itself in relation to accidents. The psychology of the person who

happened to be a driver was studied more than the psychological processes of driving.

From the early 1960's there was some interest in the use of instrumented cars that made possible the measurement of the driver's G.S.R., heart rate, blood pressure, etc..., during actual performance. The concern again was usually to correlate such indices with accident records, without enquiry into the mediating stages with accident involvement. The paradigm of research, in short, was still narrowly focussed on the driver himself as somehow the causal origin of accidents, although there was now the effort at least to examine driving itself.

In England, in the mid-60's, Quenault (1966) began to collect data from more natural driving conditions, by means of a check-list method for use by in-car observers. The observations made covered aspects of the interaction of driver, car and road, such as the number of gear changes made, vehicle speed, and the frequency of use of the rearview mirror. 'Near misses' defined in terms of sudden braking and lane changing, were also included, though in fact the idea of using such incidents as a means of identifying hazardous situations (which they called 'traffic conflicts') had occurred to researchers in the U.S.A. some years earlier (Perkins and Harris, 1959). The series of studies which Quenault began initiated the observation of driving in the conditions and contexts in which the accidents occurred. Whereas before, the attempt had been made to predict accident involvement from outside the driving environment, the possibility now became available of examining driving in its development into accidents. However, certainly Quenault was concerned in his studies to correlate his observations with the driver's accident record. Accidents were still seen as the product of driver actions in isolation from particular road and traffic contexts.

In subsequent years a number of distinct lines of development became evident that were based upon similar observation methods, and using the concepts of driver 'error', traffic conflicts, and accident hazards. The latter of these, with which I have been most involved, was preceeded by a performance evaluation follow-up study of Driver Education (Shaoul, 1974). What we did was to take a standard drive route, and ask the young people who had been involved in our Driver Education course, to drive over it, while accompanied by an observer who then made notes on their performance as dictated by the content of the educational course. The results are not particularly relevant to this discussion, except for the indication that driver behaviour varied more with the road and traffic location than with the difference in training status. The conclusion suggested by this was that the behavioural causes of accidents and of safe driving control are primarily circumstantial in nature. At that time however, the observations made reflected the content of instruction rather than considerations of hazard and accident likelihood.

Jones (1978) in California and Forbes (1975) in Michigan carried out similar studies aimed at standardizing on-road observational methods; the Jones study originated in the needs of Driver Education. In both studies, as in the Salford project, the observations to be made could be pre-specified as regards their location on a standard drive route, and their significance evaluated by means of categorical check-lists or observer ratings of apparent accident likelihood. In none of the three studies was external validation data presented, the authors being satisfied with content validation. The development and standardisation of the method of data collection took priority over other considerations.

An approach to the problem of observing driver behaviour so as to relate it to accident criteria makes use of the notion of 'driver error'.

Such a tactic was adopted by Harvey, Jenkins, and Sumner (1975), in England, using a car equipped with a video camera and recorder. Thus they could sit in the car with the driver, give him route directions, and make preliminary notes on the 'errors' made, while a permanent record of the road and traffic ahead was being made. The identification of 'errors' and their evaluation in terms of 'severity' or accident likelihood were both subjective, but the technique in this case was shown to produce significant and strong relations with accident data. It was particularly important that, taking the cue from the developing field of 'traffic conflicts' research, the authors correlated their observations with the accident records of the roads where the 'errors' were observed, rather than those of the drivers observed.

The 'error' concept has also been used in on-site investigations of accidents. This procedure involves a team of research workers visiting the site of an accident, as soon as possible after it has happened, so as to obtain information from participants and any observers before any distortion has begun. The expectation is that such information will be more accurate and can be more comprehensive and detailed than is usually the case with officially-reported data. However, one could object that the accounts of participants are likely to be distorted by the need to disclaim responsibility, while it seems likely that many accidents happen because the road user in unaware of the danger. In general, one may say, the specification of 'errors' in driving is subjective, and thus the identification of 'causes' is likely to be attributive, with all the difficulties of variability, over time and between observers, that this involves. Moreover as a research method it is evaluative rather than analytic in nature, yielding only simple categorical information (e.g. 'serious' and 'minor', 'correct' and 'incorrect' and 'suitable' and 'unsuitable' behaviour).

Finally to be mentioned is the Traffic Conflicts Technique. Strictly speaking it is a method developed by traffic engineers to permit the estimation of the relationship between accidents and the road and traffic environments. Although there is now considerable variation in the definition of conflicts and in the methods of observation used, it was originally used to refer to 'evasive action' by drivers as indicated by the appearance of brake lights and lane changing. The method used relies on external, rather than in-car, observers, and has tended to be most often used to assess conflicts at specific road sites. The appearance of vehicle brake lights and swerving, seemed to be ideally objective criteria of the occurrence of accident risk. As it emerged however, the results of correlating conflicts with accident data were variable (Williams 1980). It was not at first realized that the identification of 'evasive' action involves a judgment by the observer (about what is being evaded), and that while brake lights and vehicle lane changing may indicate evasive action, the hazard being evaded need not be an accident hazard still less the kind that developed into the criterion accidents. Momentary congestion and other types of hold-ups, pre-caution and driver initiated actions, are among the reasons for brake use, apart from driver reaction to accident risk. The objective criterion in other words, appears to have been revealed as also selective.

Again, it is clear that the technique can only identify those risks that drivers themselves perceive and react to. However, accidents may be the result of situations where the driver is unaware of the danger or has insufficient time to react so as to control it.

The paradigm of research can be seen to have changed quite sharply over the last twenty years. From a position where accidents were seen as somehow the products of the driver personally, and causality was established by statistical association, they are now seen as the results of

certain conditions in driving, and the search for causes has begun to move from the driver personally to the road and traffic situation.

## THE DRIVING SYSTEM AND ACCIDENT HAZARD

Traditionally the conception of the transport and driving system has been three phased - the driver, the car and the road. Such a description does not of course indicate how the system operates. It cannot be used to specify how the system elements interact to produce accidents. In developing our accident hazard perspective therefore, we began by redefining the system. The forms of interaction between the driver and the car, we call driving procedures - examples are pressing (or releasing) the foot pedals, manipulating the steering wheel, etc... The forms of interaction between the car and the road environment on the other hand, we call vehicle manoeuvres, such as cornering and changing lane, etc... All manoeuvres are the results of driver procedures, though not all procedures result in manoeuvres, e.g. visual 'scanning' procedures.

Accidents are rare events in the life of a driver. Yet if one defines vehicle movement on the roads as a series of manoeuvres, one can see quite readily that the risk of collision is constantly very great. Vehicles and other road users are continually approaching and passing each other at very short time gaps, and with very small separation distances. Yet the number of accidents that happen is, relatively speaking, very small. The fact is, there seem to be several system constraints which operate to prevent accidents.

These we call the physical, the symbolic, and the socio-legal forms. The physical one consists of the design of the road, its 'geometry', and certain types of road 'furniture' (road bollards, pedestrian refuges, etc...), which limit the total amount and shape of the space available for the traffic to manoeuvre in. Thus different types of intersection design - roundabouts, 'Y' and 'T' junctions, etc..., signify variations in the kinds

of manoeuvres and interaction that are possible. Symbolic constraints are the road signs and markings, traffic lights and other devices whose significance and effects depend on the symbolic meaning they have for drivers. Lastly, the socio-legal constraints consist of the rules, conventions and accepted standards governing driving, whether or not they exist as or are supported by legal sanctions. Examples are the official 'Highway Code', the laws governing 'who' may drive and 'where', speed restrictions, etc...

Now, in our theorizing we postulated a relationship between the road and the way the traffic moves and interacts within it. If manoeuvres can be defined as forms of interaction between the car and the road, then one can say that certain types of manoeuvres will tend to occur at certain types of road locations. Cornering will take place mostly at bends and road intersections; overtaking manoeuvres will take place on road sections which are wide enough to permit vehicle passing. Thus to some extent the nature of the manoeuvres that take place are constrained or determined by the actual amount and shape of road space available at the time.

The influence of these constraints extends beyond the determination of vehicle manoeuvres, to the forms of interactive relations that arise between road users. 'Overtaking' and 'passing' have already been mentioned as requiring a certain amount of road space to the side and ahead.

It seemed that, based on our research experience and on this theoretical understanding, pre-accident hazard could be defined in terms of a 'configuration' of road location, road user positions, manoeuvres and relations characterizing the vehicles and persons present.

Theoretically, we were saying that an accident is always possible, that there is no situation on the roads of which one can say categorically

that an accident is impossible. To identify a condition on the roads as hazardous means only that an accident is more likely than usual. In other words, the possibility is always present and varies only in likelihood. Conversely, one can say that all accidents are in principle predictable, that is, they are all preceded by a condition or configuration of road and traffic which permits one to predict that the accident will happen. This meant, of course, that observing hazardous situations implied selective sampling of certain kinds of road and traffic situations, those that relate statistically to accidents.

A first study which was begun at the University of Salford, in England, could properly be called a demonstration project, rather than a scientific study, insofar as our intention was to illustrate the objectivity of accident Hazard. What we did was to specify a standard route on the public roads of about 27 miles in length, and have groups of drivers drive over this route accompanied by two observers. The observers for that study were former Government license test examiners with many years experience, so we had to take time to train them to report what had happened as distinct from their inference about the error the driver had made. The following illustrates some of the correlational findings.

These data reflect associations between a variety of predictor variables, defined in terms of the roads and traffic movements necessary to the pre-selected route. 'Access Roads' means effectively the number of side roads along the route; 'possible manoeuvres' refers to the number of manoeuvres the driver can carry out at the intersections contained in the route Zones (the manoeuvres considered were: left turns, right turns, and 'straight on' manoeuvres); 'decision points' refer to the number of major and minor intersections in the zones; and the 'flow path conflict points' refer to a method of calculating, as points of traffic conflict, the sites

of intersections where the manoeuvres noted earlier can conflict. In other words, the manoeuvre paths are drawn on a diagram of the intersection, and the points where they converge or intersect are counted (Matsun, Smith and Hurd, 1955). On average about 30 hazards per drive were reported, the zones numbered 52 and were on average 0,49 miles long. The criterion accidents had happened over the previous 4 years.

The important thing about the table is that the predictor variables correlate, with the accidents to about the same extent as they do with the hazards. We understand such correlations as confirmation that hazards and accidents are generated by the same kinds of causal sequences, and that these can be sampled and observed quite readily. Mostly these predictors consist of counting traffic interaction points at intersections. Most of the incidents reported as hazards involved no evasive action, (some 70%), so one can say that accident hazard is to that degree independent of the driver's awareness and experience. Of course the critical question concerns how the observers were able to distinguish an accident from the other types of traffic hazard.

The replication study we next carried out, at Newcastle University, was intended to explore the reported hazards in more detail, by examining the 'configurations' of those hazards characterized by 'evasive action', as compared with those lacking such action, and those incidents reported as relatively 'safe' (i.e. those which are hazardous, but not reportably so.). There was also the problem that statistically associating 'hazards' with accidents would not necessarily reveal very much about the role played by individual configuration variables. This had been anticipated, and was partly the reason for the focus on the 'forms' of the roads, the manoeuvres, and the relations between road users. The facility offered, of a comparison between hazards and accidents in such terms, seemed to be one

way of going beyond the mere strength of association between them. If a certain proportion of hazards are found to be characterized by 'following' relations, during 'cornering' manoeuvres at roundabouts, and the recorded accidents exhibit similar proportions, then accident prevention should benefit accordingly.

I cannot speak of the results with confidence at the moment, since I had to leave the project before it was complete and I am scarcely aware of them. I hope that they will be the subject of publication in the not-too-distant future.

It is worth spending a few moments one the directions for future research, however. First and most obviously, there is the problem of a hazard criterion. The hazard studies I have mentioned did not rely upon braking or vehicle swerving in order to identify near accidents. The observers simply reported the nature of those incidents that they 'felt' to be particularly hazardous. Mostly these were characterized by particular road user relations, and the fact that most accidents happen in the form of collisions tends to corroborate this. The braking/vehicle swerving criterion of the traffic conflicts technique, appears to have turned out to be ambiguous - at least when used alone. From within the car any ambiguity which is apparent to an external observer, is likely to be less, since an in-car observer can see the nature of the road and traffic conditions that gave rise to the driver's action. On the other hand it should not be forgotten that the accident hazards so identified are those that the drivers themselves have perceived and that the data will be to this degree deficient.

Aside from the problems of objective criteria the advantages of an objective view of accident hazard are perhaps more clear. Driver training should benefit from the substantiation of the major forms of traffic haz-

ard, which will help define training objectives. However, it seems likely that the value of training and of education will be realized only after a thorough and careful analysis of skill acquisition, including the identification and coping skills learned in respect of accident hazard.

TABLE I

CORRELATIONS OF ROADS, MANOEUVRES AND FLOW PATH VARIABLES WITH ACCIDENTS AND PERCEIVED HAZARDS

| Variable | Accident per zone | Hazards per zone |
|---|---|---|
| ROADS | | |
| No. Access roads on right passed per zone | 0.38 | 0.33 |
| No. Access roads on left passed per zone | 0.60 | 0.67 |
| Total No. Access roads (R + L) passed per zone | 0.58 | 0.61 |
| MANOEUVRES | | |
| No. "Possible" manoeuvres per zone | 0.68 | 0.66 |
| No. of "Decision Points" per zone | 0.67 | 0.68 |
| No. of "Straight On" manoeuvres per zone | 0.61 | 0.53 |
| No. of junctions crossed per zone | 0.49 | 0.43 |
| No. of roundabout "Decision Points" per zone | 0.42 | 0.42 |
| FLOW PATH CONFLICT POINTS | | |
| No. Potential VEH./VEH. conflict points per zone | 0.63 | 0.64 |
| No. Potential VEH./VEH. conflict points (test route) per zone | 0.66 | 0.70 |
| No. Potential PED./VEH. conflict points per zone | 0.68 | 0.65 |
| No. Potential PED./VEH. conflict points (test route) per zone | 0.66 | 0.62 |
| Total potential VEH./VEH. + PED./VEH. C. points per zone | 0.65 | 0.65 |
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## REFERENCES

FARMER, E. and CHAMBERS, E.G. (1939). " A study of accident proneness amongst Motor Drivers." Industrial Health Research Board, LONDON.

FORBES, T.W. (1975). "Driver performance measurement based on dynamic driver behaviour patterns in rural, urban, suburban and freeway traffic. Accident Analysis and Prevention, 7, 257-280.

HARVEY, C.F., JENKINS, D. and SUMNER, S. (1975). " Driver Error." T.R.R.L. report 149 uc, Transport and Road Research Laboratory, Crowthorne, ENGLAND.

JONES, Margaret Hubbard (1978). "Driver performance measures for the safe performance curriculum." Traffic Safety Centre, University of Southern California.

MACDONALD (1964). "Suicide and homicide by automobile." American Journal of Psychiatry, 121, 366 - 370.

MATSUN, J.M., SMITH, W.S. and HURD, F.W. (1955). Traffic Engineering. New York, McGraw Hill.

PERKINS, S.R. and HARRIS, J.I. (1969). "Traffic conflicts characteristics - accident potential at intersections." H.R.B. REC. 225, 35-44.

QUENAULT, S.W., "Driver behaviour - safe and unsafe drivers." T.R.R.L. report LR70. Transport and road research laboratory, Crowthorne, ENGLAND.

RISK, A. and SHAOUL, J. (1979). "Driving experience, exposure to risk and measures of safe performance." Road Safety Research Unit, University of Salford, ENGLAND.

SHAOUL, J. (1974). "The use of driving tests as an alternative criterion to accidents for evaluating driver education. Road Safety Research Unit, University of Salford, ENGLAND.

SHAW, L. and SICHEL, H. S. (1971). Accident Proneness, Pergamon Press.

TILLMAN and HOBBS, L.H. (1949). "The accident prone automobile driver", American Journal of Psychiatry, 106 (5), 321-31.

VITELES, M.S. (1932). Industrial Psychology. W.W. Norton, New York.

WILLIAMS, M.I. (1980). Validity of the Traffic Conflicts Technique Australian Road Research Board, Internal Report AIR2390-1